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THE DEVELOPMENT OF AN EXPLOSIVE DRIVEN, SHUTTER-TYPE, HIGH PRESSURE RELEASE

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THE DEVELOPMENT OF AN EXPLOSIVE DRIVEN, SHUTTER-TYPE, HIGH PRESSURE RELEASE

Prepared by
Rayner A. Montgomery and E. Eugene Kilmer

ABSTRACT: An investigation was conducted to determine the feasibility of using a shutter-type pressure release for a 1-1/2-inch shock tunnel. This device was operated by an explosive driver producing opening times in the order of 500 microseconds. The shutter mechanism was tested up to 500 psi differential pressure.

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THE DEVELOPMENT OF AN EXPLOSIVE DRIVEN, SHUTTER-TYPE HIGH PRESSURE RELEASE

This investigation was undertaken as a possible method of hypersonic shock tunnel flow improvement. This work was performed under NOL Task No. 363 by the Ballistics Design and Operations Division of the Ballistics Department with the support of the Explosion Dynamics Division of the Explosions Research Department.

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R. E. ODENING
Captain, USN
Commander

A. E. Seigel
A. E. SEIGEL
By direction

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REFERENCES

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INTRODUCTION

In the hypersonic shock tunnels, it is desirable to eliminate all disturbances which tend to detract from the uniformity of the flow. A reduction in the magnitude of these flow disturbances would improve the reproducibility of the flow in the test section. Presently, metal diaphragms are used at the muzzle end of a straight-through shock tunnel. These diaphragms require a pressure buildup in order to be opened. This tends to reflect the incident shockwave, thus increasing the disturbance in the shock tunnel flow.

The purpose of this investigation was to design and develop a fast-acting valve which would improve flow conditions and reduce costs compared to metal diaphragms. A sliding shutter-type release mechanism was designed and tested. This device was actuated by an explosive driver which was loaded with various amounts of smokeless powder. The functioning of the shutter was observed by using a high-speed camera to record the motion. In the fastest operation, the shutter required 440 microseconds to uncover the 1-1/2-inch diameter bore. It was concluded from the functioning time of the shutter that the valve should be acceptable for evaluation in the 1-1/2-inch shock tunnels.

The following points of interest were studied:

a. The sliding shutter mechanism - A study was made of the parameters affecting the operation of the sliding shutter including, among others, the mass of the shutter and the maximum force the mechanism would withstand.

b. The explosive driver - The design of the explosive driver was made to incorporate the fastest functioning time yielding optimum operating conditions for the sliding shutter.

c. The efficiency of the system - A study was made of the operating parameters from the test data, and the efficiency of the system was determined.

SHUTTER-TYPE RELEASE

This unit was designed so that a shutter slides in a housing across a 1-1/2-inch diameter orifice. The shutter is a rectangular piece of aluminum plate with a 1-1/2-inch diameter hole in it. This shutter is positioned by a recess in the

housing and is moved from closed to open position by an explosive driver. A sectioned view of the assembly is shown in figure 1. A view of the unit in its closed and open positions is shown in figure 2. Taken under consideration, in the design of the shutter unit, were the deflection of the shutter while holding the loading pressure, the shutter mass, and the compressive strength required to withstand the expected acceleration and deceleration without damaging the components.

EXPLOSIVE DRIVER

The explosive driver was designed from the Naval Ordnance Laboratory WOX-10A Explosive Driver. This driver was modified in the following ways:

a. The resistors, which are normally in parallel with the two WOX-26A Actuators, were removed. This was to facilitate the use of a low voltage power supply.

b. The capsule, normally loaded with one gram of Unique Powder, was loaded with various weights of SR 4990 Smokeless Powder. The smokeless powder was chosen because it has a shorter pressure rise time and would therefore be expected to bring about a more rapid shutter motion.

c. The piston was increased from 1.3 inches to 2.6 inches in length to produce the necessary increase in displacement.

d. Allowances were made in the design so that piston over-travel would not affect the operation of the shutter or damage other parts. The sudden stop of the driver piston at the end of its travel produces extremely high forces which may cause deformation.

e. The body was modified to accept the longer piston and also to accept a shear pin. The sectional view of the explosive driver in figure 3 indicates the arrangement of the explosive components and associated parts. The two WOX-26A Explosive Actuators were connected in parallel in the electrical circuit to shorten the inherent delay time of any single actuator and to gain reliability of functioning. The actuators were placed in a manner so that each was directed toward the powder capsule. Several weights of SR 4990 Smokeless Powder were used in the capsules, depending on the tests involved.

MONITORING EQUIPMENT

A block diagram of the test equipment is shown in figure 4. In order to obtain displacement of the shutter with respect to time, a rotating-mirror framing camera was used to observe the movement of the shutter across the 1-1/2-inch diameter orifice. To obtain the force exerted by the explosive driver, a pressure measurement was required. A pressure sensing device (ref. (1)) which produces an electrical signal was adapted, as shown in figure 3. The oscilloscope trace of this signal was recorded on photographic film for the purpose of calculating the system's efficiency.

RESULTS AND DATA REDUCTION

Various weights of smokeless powder were compared in order to determine an optimum base charge in the driver. The efficiency of the system was taken to be the ratio of work done in moving the piston to the energy available in the powder. The work was obtained by measuring the area under the force displacement curve. The energy was taken to be the theoretical impetus (ref. (2)) (foot pounds per pound of propellant). The preliminary test with 1/2-gram capsules of SR 4990 Smokeless Powder showed the efficiency to be about 43 percent, as shown in Table I. It was decided that the shutter could be driven at a greater velocity by increasing the force during the stroke. This was accomplished by allowing an initial pressure buildup through the use of shear pins placed through the driver body and piston rod. A typical trace of the pressure produced by the smokeless powder while pushing the driver piston under the load of the shutter mechanism and the shear pin is shown in figure 5. Several different diameters of shear pins were tried while holding the shutter and piston weight constant (150 grams). The results of six tests, as shown in Table I, indicate that the efficiency could be increased to approximately 80 percent by proper selection of base charge and shear pin diameter. Also, it can be seen that the shutter velocity is increased when a shear pin is used.

A typical sequence of high-speed photographs of the shutter mechanism uncovering a 1-1/2-inch orifice is shown in figure 6. The camera was operated at a speed that would give a 40-microsecond spacing between frames. A plot of the opening characteristics versus time for Test No. 5 is shown in figure 7. In order to obtain a general indication of performance, the values of peak pressure and shutter opening time are plotted in figure 8. These six tests were conducted at 250 psi pressure

differential. Preliminary tests performed at 500 psi indicate that the shutter will operate satisfactorily in the higher pressure differential.

CONCLUSIONS

During the limited number of tests conducted, this device consistently operated within 640 microseconds. This is considered to be acceptable for evaluation in the 1-1/2-inch diameter shock tunnel.

The best functioning time, as indicated from test performance, was found to be 440 microseconds with 250 psi differential pressure. The explosive driver shutter-type mechanism functioned satisfactorily up to the designed 500 psi differential pressure.

Increased performance and efficiency of this device was obtained by using a holdback technique.

The demonstrated feasibility of this device indicates that the next evaluation should be conducted in a shock tunnel.

The rapid opening time and the smooth continuous opening produced by this mechanism suggests its usefulness in other applications.

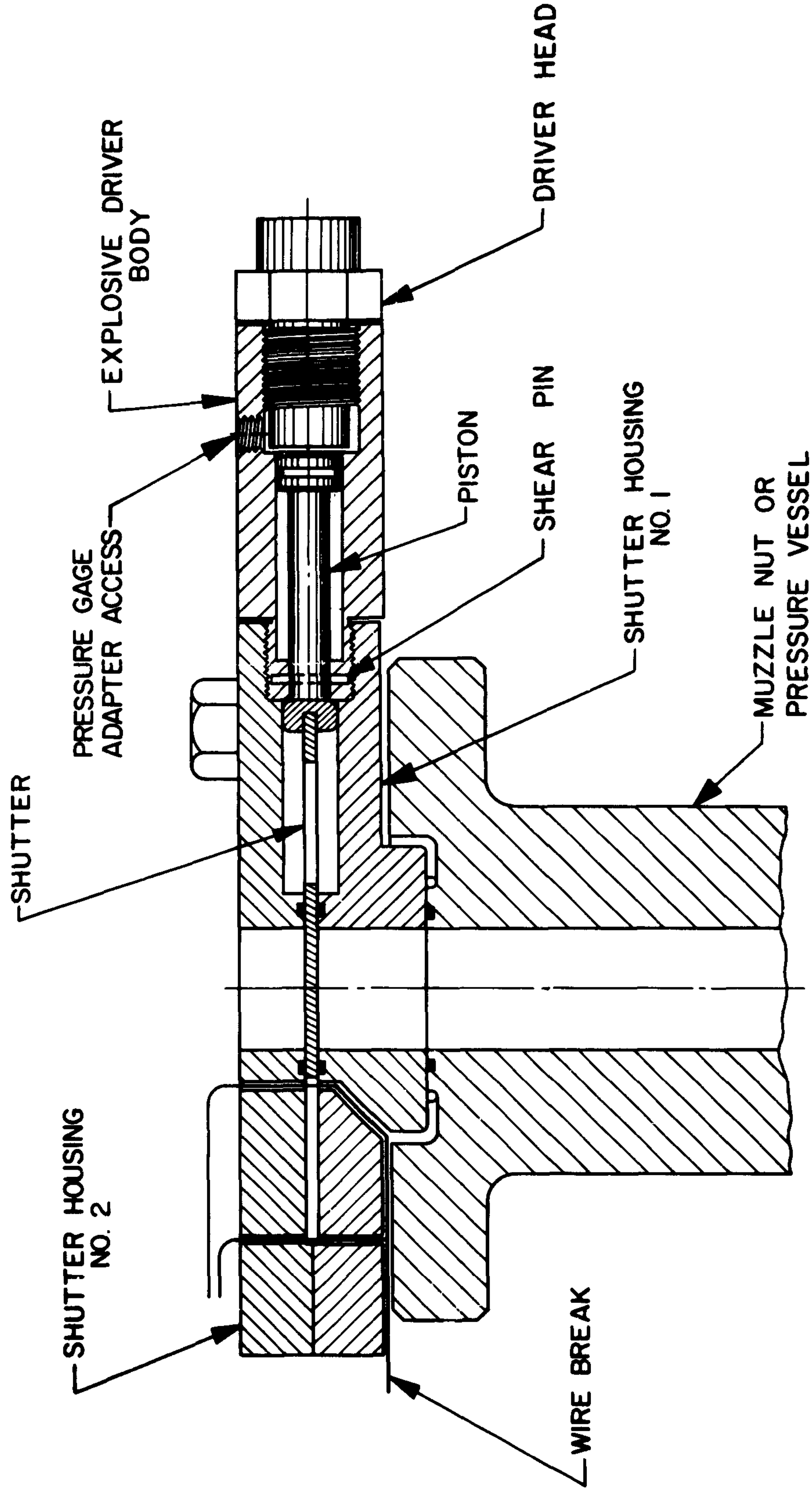
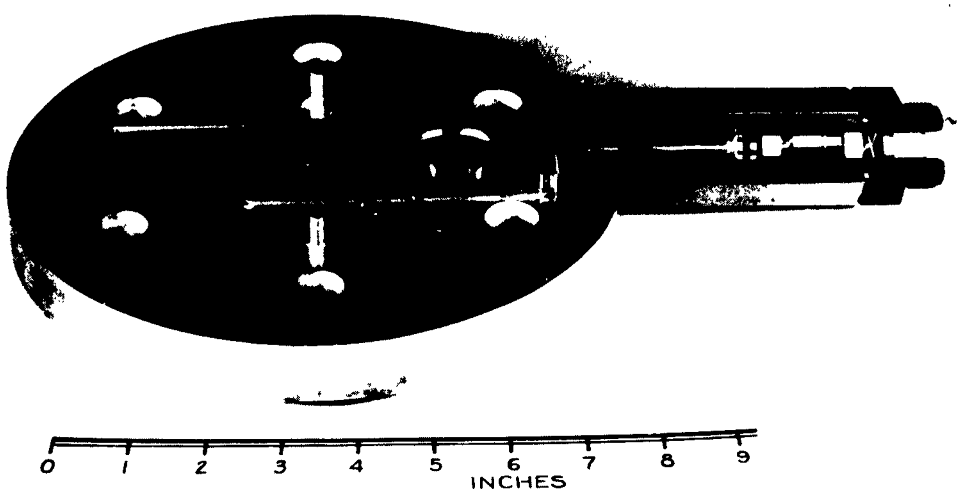
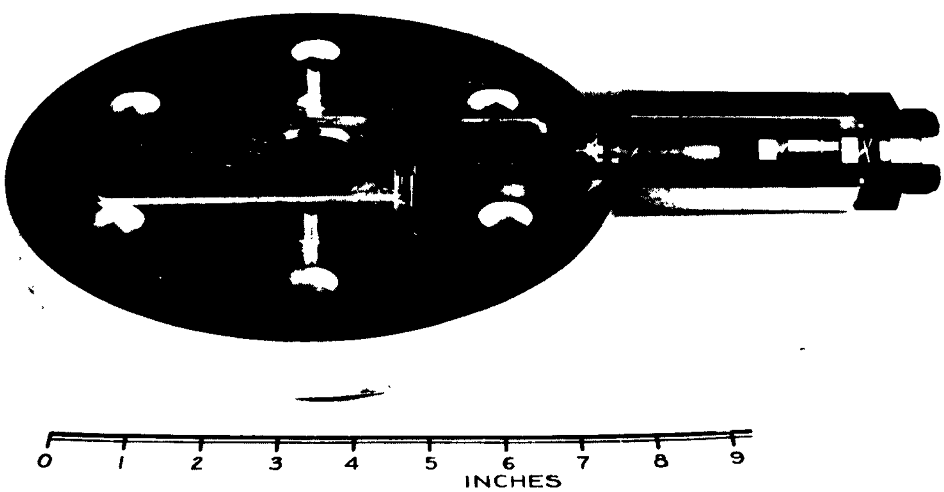


FIGURE 1. SHUTTER ASSEMBLY.
(SECTIONED)



SHUTTER CLOSED



SHUTTER OPEN

FIGURE 2. SHUTTER ASSEMBLY IN CLOSED AND OPEN POSITION.

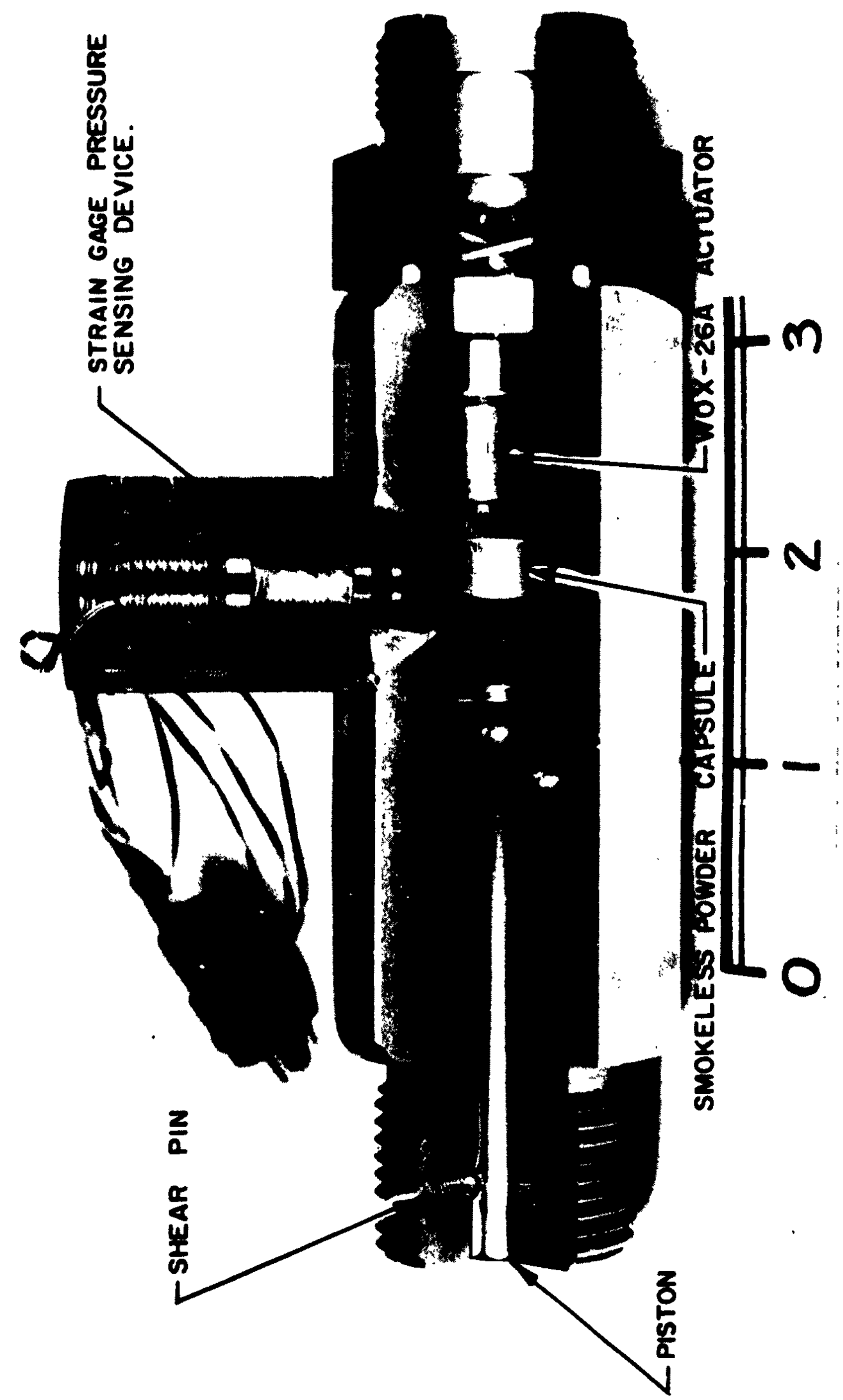


FIGURE 3. EXPLOSIVE DRIVER AND PRESSURE MONITORING DEVICE.

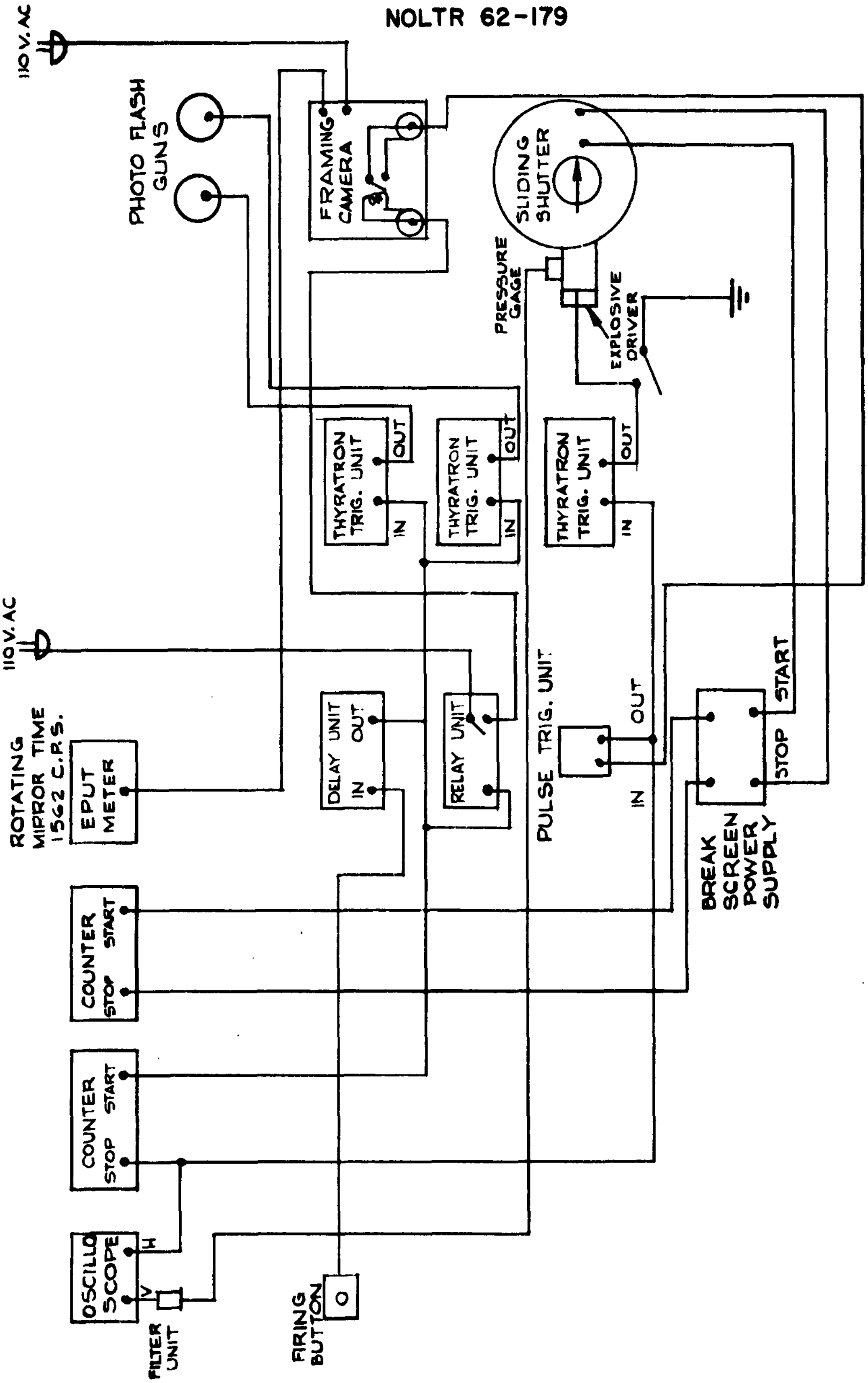
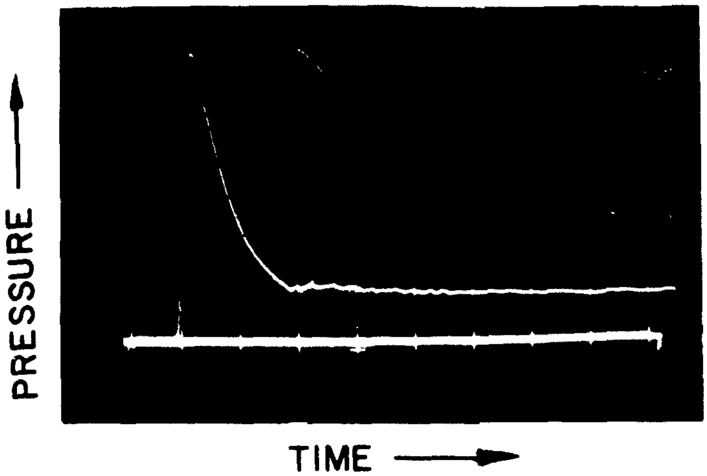


FIGURE 4. SHUTTER MONITORING SYSTEM



TIME : 1 CM. = 500 μ SEC.

PRESSURE : 1 CM. = 2770 P.S.I.

FIGURE 5. TYPICAL PRESSURE TRACE FROM THE EXPLOSIVE DRIVER IN THE SHUTTER ASSEMBLY.

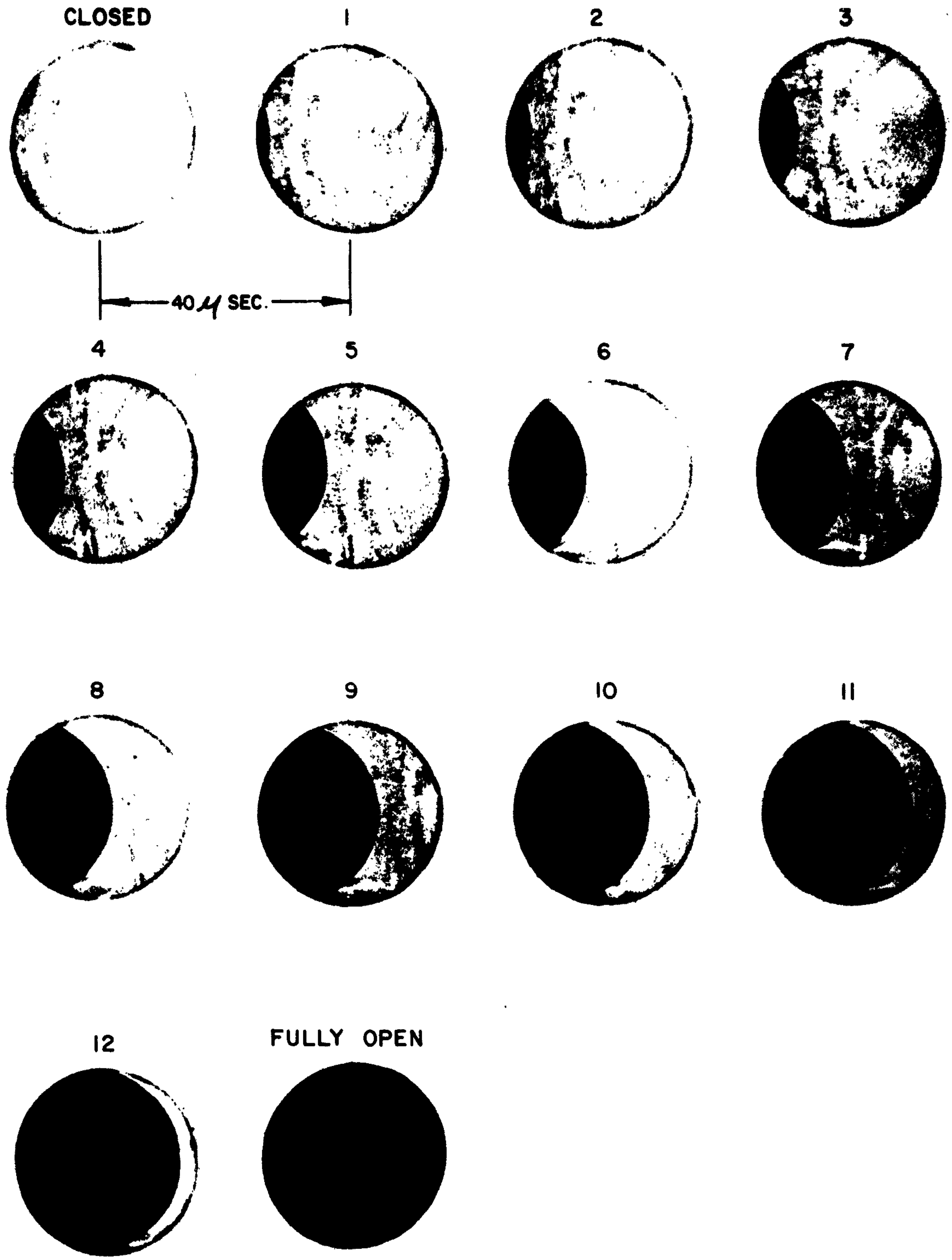


FIGURE 6. HIGH SPEED PHOTOGRAPHS OF SHUTTER OPENING.

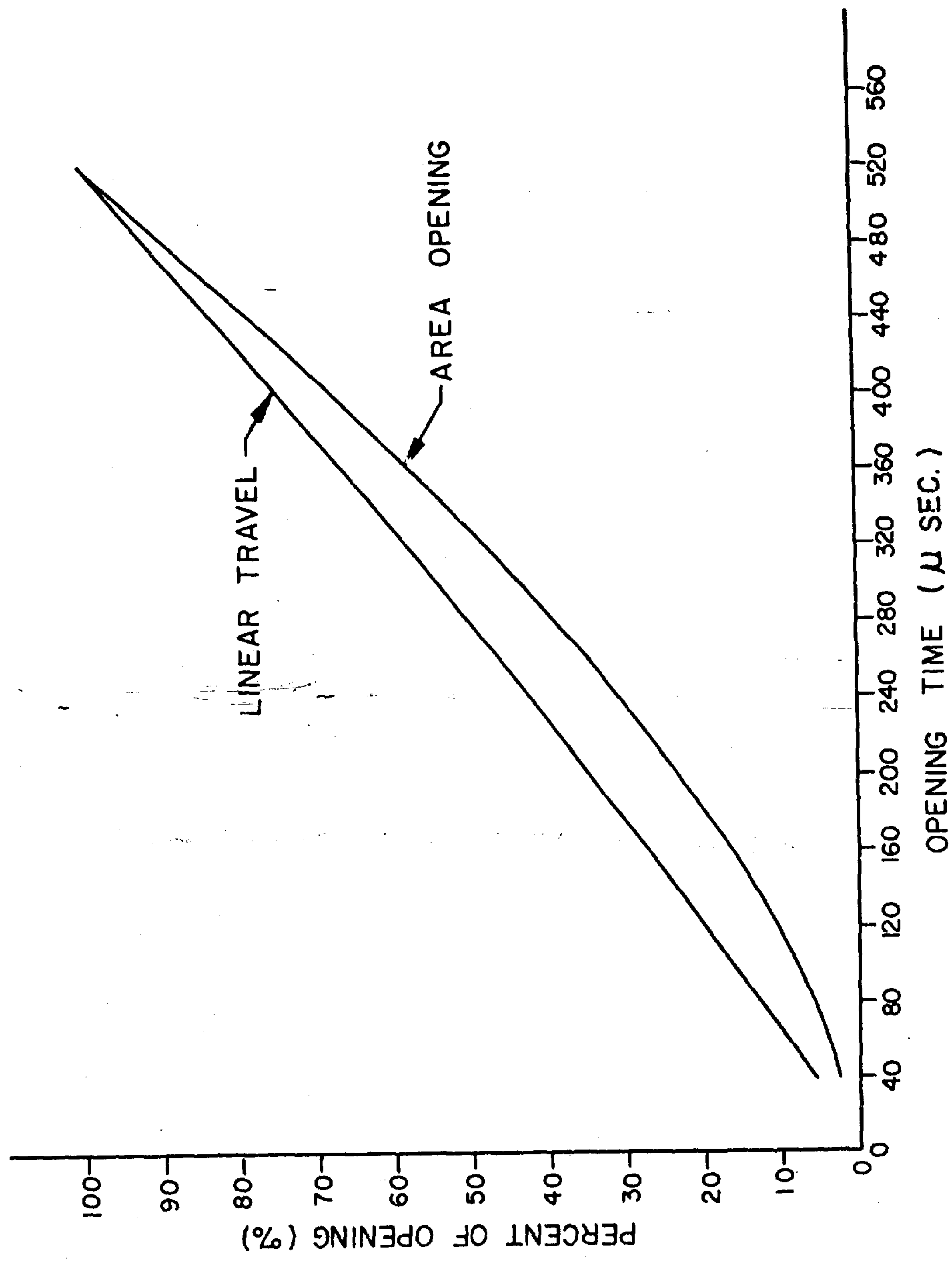


FIGURE 7. TYPICAL OPENING RATE

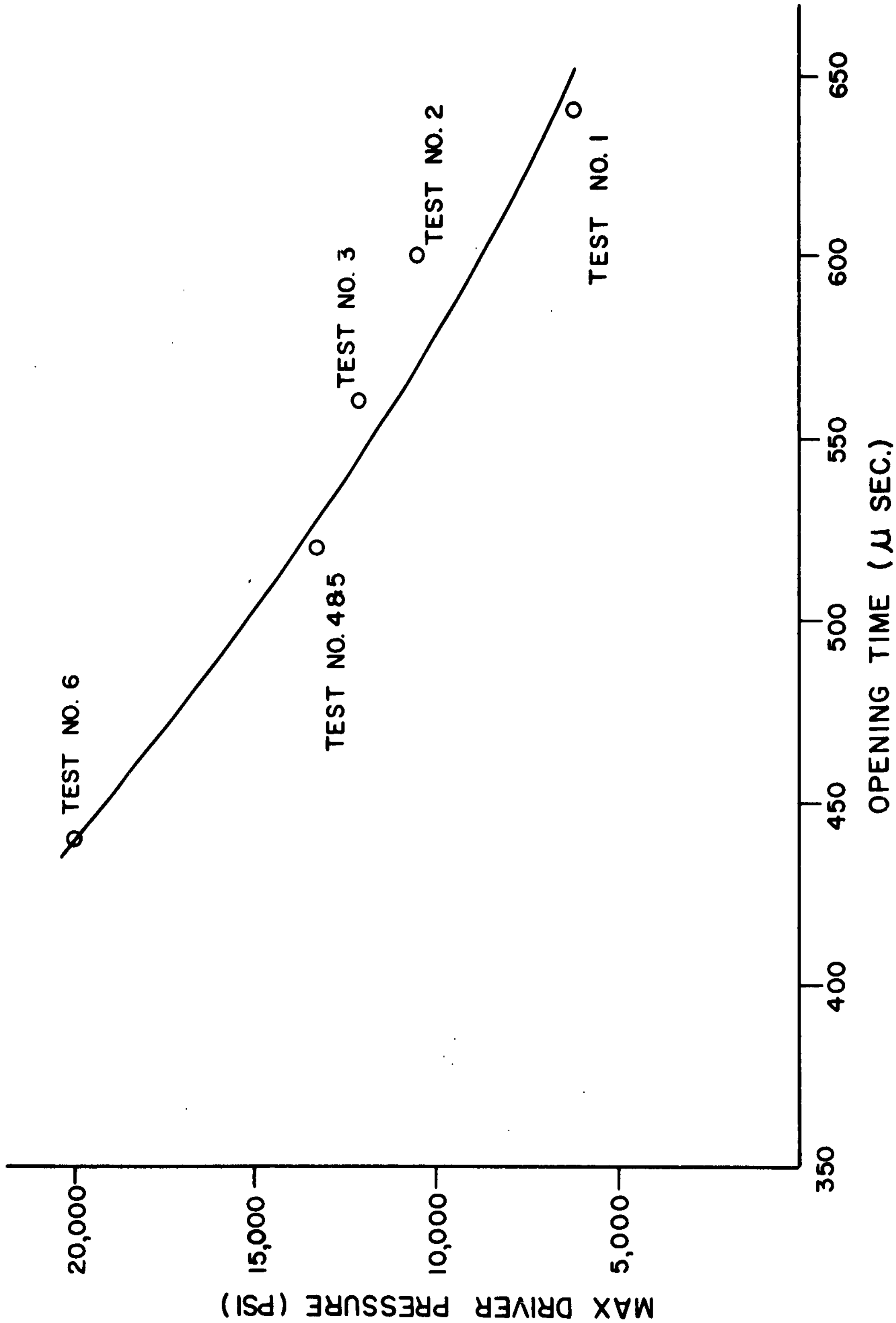


FIGURE 8. HIGH PRESSURE RELEASE PERFORMANCE CURVE

TABLE I

HIGH PRESSURE RELEASE PERFORMANCE DATA

TEST		1	2	3	4	5	6
Shutter							
Opening Time*	microsec.	640	600	560	520	520	440
Explosive Driver							
Explosive Weight	gms	0.50	0.50	0.50	0.60	0.60	0.75
Shear Pin Release Pressure	psi	None	3,000	4,000	3,000	3,000	5,000
Maximum Pressure	psi	6,240	10,550	12,200	13,300	13,300	19,950
Efficiency	%	43	66	**	61	63	80
Work	lb. - in.	2213	3371		3694	3852	6089
Impetus	lb. - in.	5100	5100		6120	6120	7650

* Shutter time measured from photographs in 40 microsec. increments
** Poor pressure trace.

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DESCRIPTORS	CODES	DESCRIPTORS	CODES	DESCRIPTORS	CODES
Shock tube	SHTU	Feasibility	FEAS		
Valve	VALU	Time	TIME		
Diaphragm	DIAP	Photography	PHOT		
Shutter	SHUE	Test	TEST		
Explosive	EXPL	Components	COMO		
Driver	DRIV				
Metal	META				
Flow	FLOW				
Hypersonic	HYPR				
High pressure	HIGP				
Release	RELE				
Pressure	PRES				

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